national accelerator laboratory

EXP-26

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ACCELERATOR EXPERIMENT--(A) Momentum Spread of the Beam from Linac
(B) Beam Emittance at 7.2 GeV

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This is a preliminary report on what one can learn from measurements using Mike Shea's multiwire profile monitors. One is installed behind the momentum-analyzing magnet in the 200-MeV transport line and another (W4) is near the upstream end of MH-50 (the last horizontal bend) in the 8-GeV transport line. Several additional monitors of the same type are now being installed in the 8-GeV line and they will provide invaluable information on the beam emittance and the tuning of the transport line.

(A) Momentum Spread of the Beam from Linac

The thickness of each wire is ~2 mils and the distance is ~23 mils (corresponding to 0.02% in $\Delta p/p$). The monitor gets the momentum distribution integrated over <u>one pulse</u>. The previous scanner gave a picture which is a composite of many pulses. Fig. 1 is a typical example of many pictures taken on November 2. The beam current was ~40 mA. Unfortunately, the beam emittance was not measured simultaneously. However, one can make the following (somewhat conservative) estimate assuming Gaussian distributions in (x, x') phase space as well as in $\Delta p/p$.

$\pi\varepsilon_x$ = Area in (x,x') phase space occupied by 90% of the beam.

$\Delta p/p$ = <u>Total</u> momentum width containing 90% of the beam.

ΔT = Corresponding energy spread.

ε_x (mm-mrad)	$\Delta p/p\,(10^{-3})$	ΔT (keV)
0	1.76	652
7.5	1.50	556
10	1.40	519
12.5	1.28	474
15	1.16	430

It is most likely that the beam emittance was such that

$$\pi\varepsilon_x \cong 10\pi \text{ mm-mrad.}$$

These values of $\Delta p/p$ are consistent with the result obtained from the pulse debunching in the booster,

$$\Delta p/p \text{ (total)} = (0.9\sim1.6) \times 10^{-3}.$$

The fluctuation of the central momentum of the beam from pulse to pulse is at most 0.3×10^{-3} so that the combined momentum spread of the beam in the booster at injection is

$$\Delta p/p \text{ (total)} \lesssim 2 \times 10^{-3}.$$

At higher currents ($\gtrsim$70 mA), one expects ~50% increase in $\Delta p/p$ due to space-charge forces. A conservative but not-too-unrealistic estimate is then

$$\Delta p/p \text{ (total)} \lesssim 3 \times 10^{-3} \text{ (speculation)}$$

which should be compared with the design specification (White Book)

$$\Delta p/p \text{ (total)} = 3.2 \times 10^{-3} \text{ (}\pm 600\text{ keV).}$$

We tend to forget that the value often quoted (1.6×10^{-3}) is <u>with a debuncher</u>. It is too much to expect this value at ~70 mA without a debuncher.

(B) <u>Beam Emittance at 7.2 GeV</u>

Another example of results from the multiwire monitor is shown in Fig. 2. The wire thickness is 1/16 inch and the distance between wires is 1/8 inch. The horizontal emittance here should be twice (or more) as large as the vertical emittance (two-turn injection). Again, assuming Gaussian distributions in phase space, we find (emittance $\pi\varepsilon_x$ and $\pi\varepsilon_y$)

$$\beta_x \varepsilon_x = (50\sim 80) \times 10^{-6}\ m^2.$$
$$\beta_y \varepsilon_y = (12\sim 15) \times 10^{-6}\ m^2.$$

Effects of momentum dispersions are very small ($\lesssim$10%).

The following discussions are based on speculations as well as on computations.

1) If the tuning of the 8-GeV line is perfect,

$$\beta_x = 50m, \qquad \beta_y = 29m$$

so that

$\pi\varepsilon_x = (1\sim 1.6)\pi$ mm-mrad and $\pi\varepsilon_y = (0.4\sim 0.5)\pi$ mm-mrad.

At 200 GeV, we should have

$\pi\varepsilon_x = (0.04\sim 0.064)\pi$ mm-mrad and $\pi\varepsilon_y = (.016\sim .020)\pi$ mm-mrad.

These should be compared with the result of recent measurements by F. Hornstra.

$\pi\varepsilon_x = 0.14\pi$ mm-mrad and $\pi\varepsilon_y = 0.08\pi$ mm-mrad.

2) If we take Hornstra'a values and scale to 7.2 GeV,

$\pi\varepsilon_x = 3.48\pi$ mm-mrad and $\pi\varepsilon_y = 1.99\pi$ mm-mrad.

This means

$\beta_x = (14.4\sim 23.0)$m and $\beta_y = (6.0\sim 7.5)$ m.

The degree of mismatching is simply too large to be real.

3) Suppose power supply #205 (MQ-03) is off by -15%. Then

$$\pi\varepsilon_x = (0.84\sim 1.34)\pi \text{ mm-mrad at 7.2 GeV}$$
$$= (0.03\sim 0.05)\pi \text{ mm-mrad at 200 GeV}$$

since there is practically no mismatching horizontally. On the other hand, the vertical emittance increases by a factor ~2.5 due to mismatching so that

$$\pi\varepsilon_y = (0.6\sim 0.74)\pi \text{ mm-mrad at 7.2 GeV}$$

makes

$$\pi\varepsilon_y = (0.06\sim0.074)\pi \text{ mm-mrad at 200 GeV.}$$

Only conclusion that can be made at this time is:

1) Beam emittance (normalized) grows in both directions by a factor >2 in the main ring (residual gas, coupling, internal target?), or,

2) The mismatching due to erroneous tuning of 8-GeV line is such that the effective beam emittance in the main ring is larger by a factor >2 compared to the real beam emittance, or, most likely,

3) Both.

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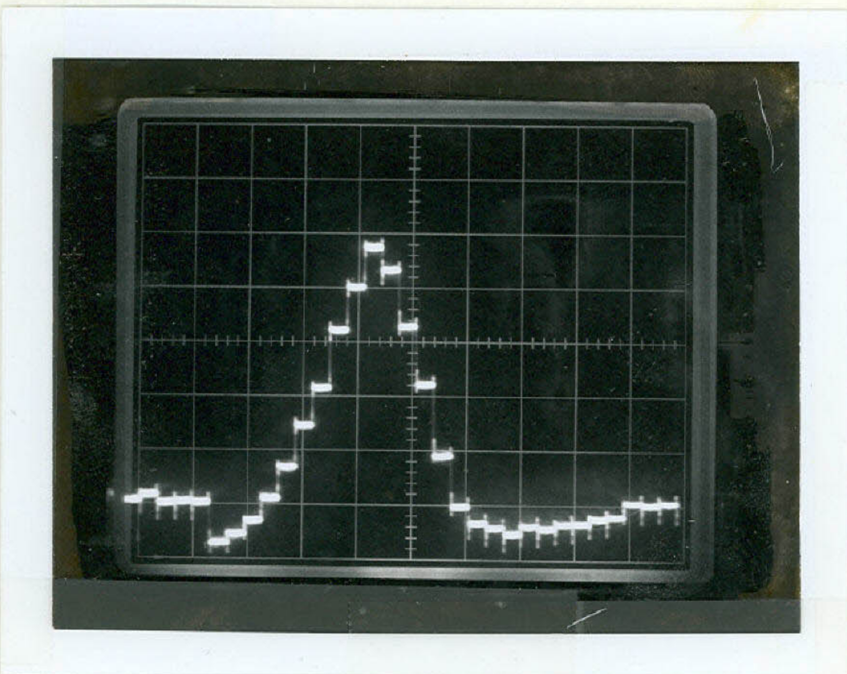
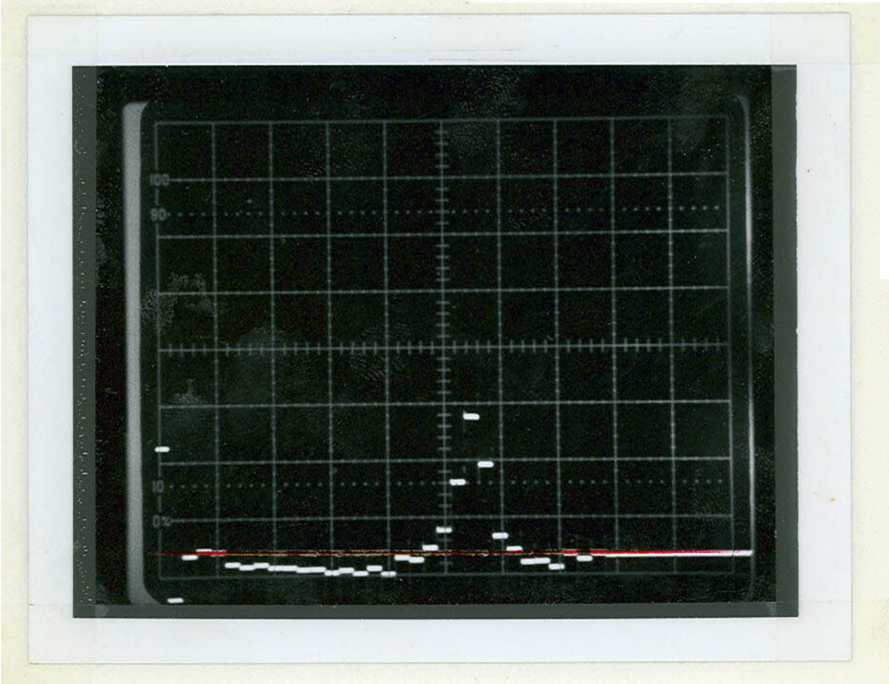
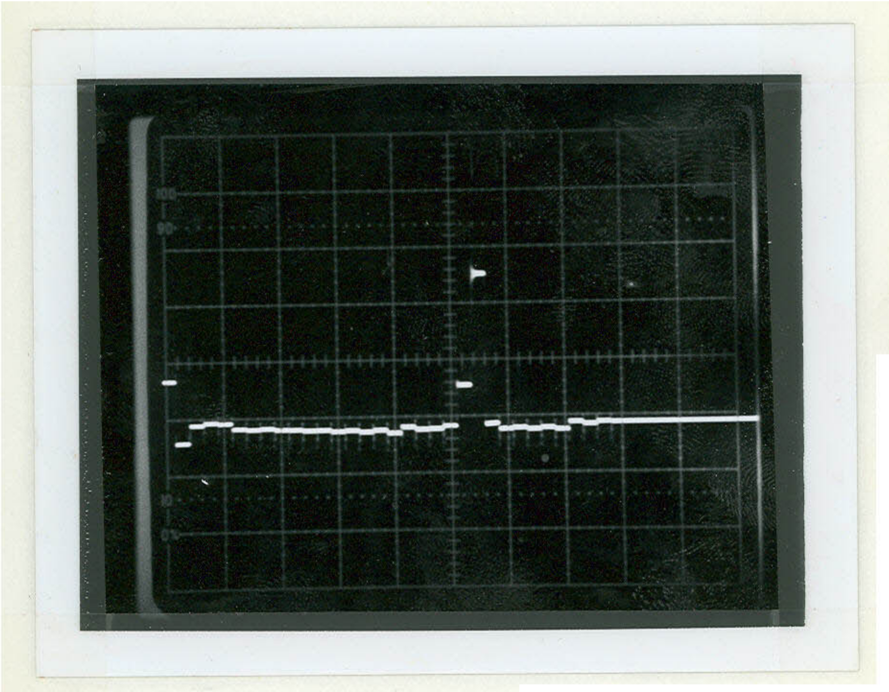


Fig. 1



Horizontal



Vertical

Fig. 2